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SYSTEM OF DISPLAYING SEA-BED IMAGES

BACKGROUND OF THE INVENTION

Imaging a considerable portion of the sea-bottom is currently done by directly submerging a camera and an illumination source linked to a ship by cables.

This technique allows for exploration of only a small portion of the sea bottom. Exploring larger portions requires towing the camera and illumination source or hoisting them back to the ship if the ship must change position quickly. This represents an inconvenience.

On the other hand, other alternative systems like the sonar are not effective in swallow waters. Further, the long wavelength associated to the characteristic frequency spectrum of their pulses limits the attainable resolution.

SUMMARY OF THE INVENTION

The system invented serves in an optimal manner to explore with high resolution the bottom of a large portion of an aqueous volume such as a sea or a lake. It only requires to be slightly submerged -one meter or less- in order to capture underwater images from a considerable depth, thus allowing for towing the system or quickly hoisting it back to the ship if the ship position must change. Further, the system may be adjusted to operate either on an expanded beam basis or on a concentrated beam basis according with the depth to image, thus optimizing illumination and resolution.

When exploring small depths, the system operates with an expanded illuminating beam, and generates two-dimensional images of the illuminated zone with a conventional TV system comprising an intensified camera and a TV monitor. When exploring regions of greater depth, a concentrated beam illuminates a small portion –namely a point- of the volume bottom. The concentrated beam is scanned in two dimensions by a scanning system and light reflected from the bottom is directed to a single detector. An electric current with sequential information of the scanned bottom region is delivered by the

detector, which allows for generating a conventional composite video signal that can be displayed on a TV monitor.

According to this description and to the invention, the system is based on a combined operation of high gain detectors and narrowband laser light illumination, and comprises at least the following elements:

- A source of pulsed light, preferably a laser, which operates in a spectral range where light attenuation in the medium –such as sea water- is minimum. The short duration light pulses may be emitted in an extended or concentrated beam. In this later case a scanning is made in a certain direction and light is partially reflected.
- An aiming/expansion system of the pulsed light beam, preferably based on galvanometric mirrors or electro-optic or acousto-optic deflectors.
- A detector of light reflected from the sea bottom. The preferred detector to be used in combination with extended beam illumination is a conventional solid-state TV camera based on a two-dimensional array of photosensitive detectors (pixels), which allows for capturing images of the illuminated area. A single photodetector should be used in case of illuminating with a concentrated beam. An electric current pulse of temporal characteristics similar to those of the reflected light pulse is then generated in the photodetector.
- An optical device coupled to the detector which may selectively act as an intensifier/shutter of the received light, and which allows light into the detector only at specific times in order to avoid undesired backscattered light from the medium entering the detector. With this optical device the reflected light is discriminated against the light backscattered by preventing light from reaching the detector for a time duration equal to the round-trip time needed by the emitted light pulse to reach the target and travel back to the detector. This device should be an image intensifier tube or a photomultiplier with a built-in gating capability. Photodetection can be selectively blocked or allowed by positive or negative biasing of the photocathode with a duty cycle that may be varied between 0 % and 100 %. Optionally additional image intensifier tubes may be cascaded to extend the system operation range.

- An electronic exploration/synchronism system which compares the energies of the emitted and detected light pulses and provides the information required for aiming the light beam and for estimating the time of flight of the pulses to avoid undesired backscattered light from reaching the detector through the image intensifier tube.
- An electronic system for processing the information received and which generates an image that can be displayed in the monitor.

In this way, a two-dimensional scanning of the concentrated light beam with the aiming system generates sequential information of the light intensity reflected by the illuminated points of the volume bottom, this information being electronically processed to generate a conventional composite video signal that can be displayed in the monitor.

In case of using an extended beam, light reflected from the volume bottom is captured by a TV camera which delivers a conventional video signal.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The system invented is composed of a laser source 1 which emits short-duration light pulses in a spectral range where the sea water attenuation is minimum and where the instantaneous direction of the illuminating beam and its size is determined by an aiming system 2 including galvanometric scanning mirrors and optionally a beam expander (not shown in the drawing).

Upon incidence on the sea bottom 11 along the aimed direction 8, a fraction of the reflected light travels toward an optical system 5 which selectively intensifies/blocks the light entering the detector 4.

The optical device 5 discriminates reflected light against light backscattered by the intermediate medium volume by remaining shut until light directly reflected from the bottom is received.

The detector 4 to be used in combination with an extended beam is an intensified TV camera which pixels receive the two-dimensional reflected beam and directly generates a two-dimensional video image. Optionally, a low noise detector incorporating internal gain by ion impact or avalanche can be used, thus amplifying the photogenerated current stored in its series register previously to a read-out of the video signal, therefore avoiding the need of an image intensifier tube.

The TV camera used for light detection in this case of extended illumination should preferably be a solid state camera based on a CCD or CMOS image sensor and includes, like all cameras of this kind, an internal two-dimensional array of individual detectors (pixels) which provide the sequential information stored in the series register of the camera to form a two-dimensional video image. The signal level corresponding to each position in the series register is determined by the electric charge photogenerated in an individual detector of the two-dimensional array. Typically the photogenerated charge in each individual detector provides information of the light power received at the spatial location of the individual detector within the whole two-dimensional array. charge chargeindividual detectors necessary to generate a two-dimensional image.

In case of concentrated beam illumination, the detector may be a photomultiplier tube, a photodiode or an avalanche photodiode where an electric current pulse is internally generated, said pulse displaying similar time-dependence characteristics as the pulse of reflected light.

The instants of light pulse emission and enabling in system 5 are controlled by an exploring and synchronism electronic system 3. The information signal received is electronically processed by a signal processing system 6 and then displayed as a two-dimensional image on the monitor screen 7.

The image intensifier tube 5 should include an active gating control of the photocathode bias voltage. The intensifier should also include a microchannel plate (not shown in the drawing) where the bias voltage may be manually or automatically varied in order to control the optical gain of the system. The intensifier may be either a second- or third-generation intensifier but in any case the system sensitivity should be optimized for the blue-green spectral region.

A diode-pumped solid state laser should be used preferably. Diffraction in the laser beam should be as low as possible in order to maximize the depth and resolution achievable for a given optical power. Ideally, a laser emitting a gausian laser beam with an M^2 parameter as close to unity as possible should be used, such as a diode-pumped intracavity converted or frequency-doubled or self-frequency-doubled infrared laser which operates on one of the 4F3/2->4I11/2 or 4F3/2->4I11/2 of Nd3+ ion or alternatively an Yb3+ based laser.

DRAWINGS

FIG. 1 – Schematic representation of the invented system.